

Respiratory Protection of Firefighters during Overhaul

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Background

Overhaul is the phase of a structural fire where hidden fires or combustion sources are searched out and completely extinguished.

Overhaul activities typically include:

- Determining CO levels,
- Protecting area of origin,
- Establishing final smoke damage and fire perimeter,
- Protecting neighboring properties from fire debris, and
- Systematically locating all hidden fire.¹

Exposures to smoke and fine particulates can result in both acute and chronic health effects, including:

- Change in spirometric measurements and increased airway reactivity.^{2,3}
- Pulmonary and systemic inflammation, accelerated atherosclerosis, and altered cardiac autonomic function.⁴

During overhaul:

- Respiratory protection is rarely utilized.^{5,6}
- Exposures to contaminants such as particulate matter and vapors in smoke present during overhaul can exceed ceiling and short-term exposure limits.⁵

1.0 Respiratory Effects Following Overhaul⁶

Twenty-five firefighters who wore no respiratory protection and 26 firefighters wearing Air Purifying Respirators (APR) with multipurpose cartridges (Scott Aviation Model 642-MPC-P100, Monroe, NC) were assessed at baseline and 1 hour after overhaul. Both groups were evaluated for:

- Exposure to products of combustion,
- Changes in spirometry measurements, and
- Changes in lung permeability.

Evaluation of both groups included:

- Forced Vital Capacity (FVC),
- Forced Expiratory Volume in one second (FEV₁),
- Serum Clara cell protein (CC16), and
- Serum Surfactant-Associated Protein A (SP-A)

Concentration of analytes in this study⁶ were similar to, or less than, the levels observed during a previous overhaul study conducted in the same region.⁵

1.1 Results

Overhaul increased CC16 in both groups, indicating increased alveolar-capillary membrane permeability.

Contrary to expectations, SP-A increased and FVC and FEV₁ decreased in firefighters wearing cartridge respirators.

Changes in FEV₁, CC16, and SP-A were associated with concentrations of specific products of combustion or carboxyhemoglobin levels.

1.2 Conclusions

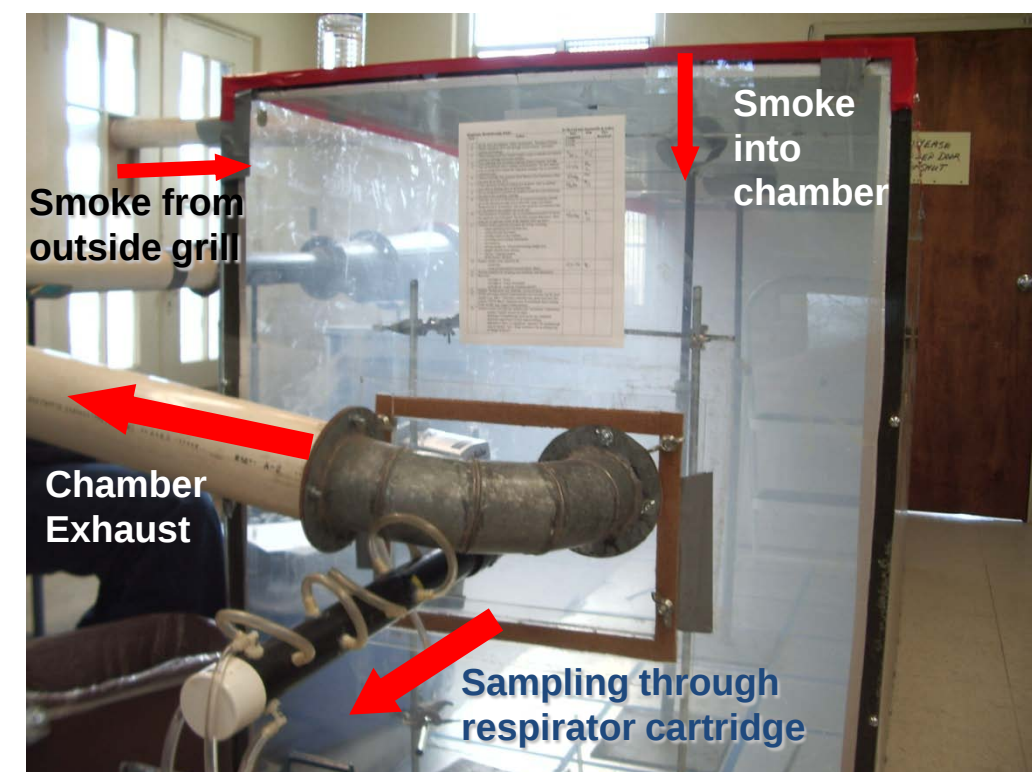
Respiratory exposures during overhaul can potentially change spirometry measurements and lung permeability.

Self-contained breathing apparatus, or more extended ventilation, is recommended during overhaul.

2.0 Method Development - APR Cartridge Evaluation during Overhaul Exposure⁷

Motivated by the previously observed health effects in APR wearers, this work developed a laboratory method to evaluate the effectiveness of multi-gas APR cartridges for protecting against representative overhaul exposures. Smoke was generated and transported to a test chamber, where air was pulled through one of 2 multi-gas cartridge or a CBRN canister at rates simulating “heavy breathing.”

- Chamber and penetration concentrations of 91 analytes were measured, including particulates, aldehydes, PAHs, hydrocarbons, and methyl isocyanate.
- Concentration of analytes generated during this laboratory study⁷ were similar to the levels observed during previous field-reported overhaul exposures.⁵
- An exposure index was determined for challenge and filtered air to evaluate relative risk from aggregated exposure.



2.1 Results

In air filtered by the APR cartridges, several analytes penetrated the cartridge.

The primary contributors to the irritant exposure index in cartridge filtered air included formaldehyde and acetaldehyde.

2.2 Conclusions

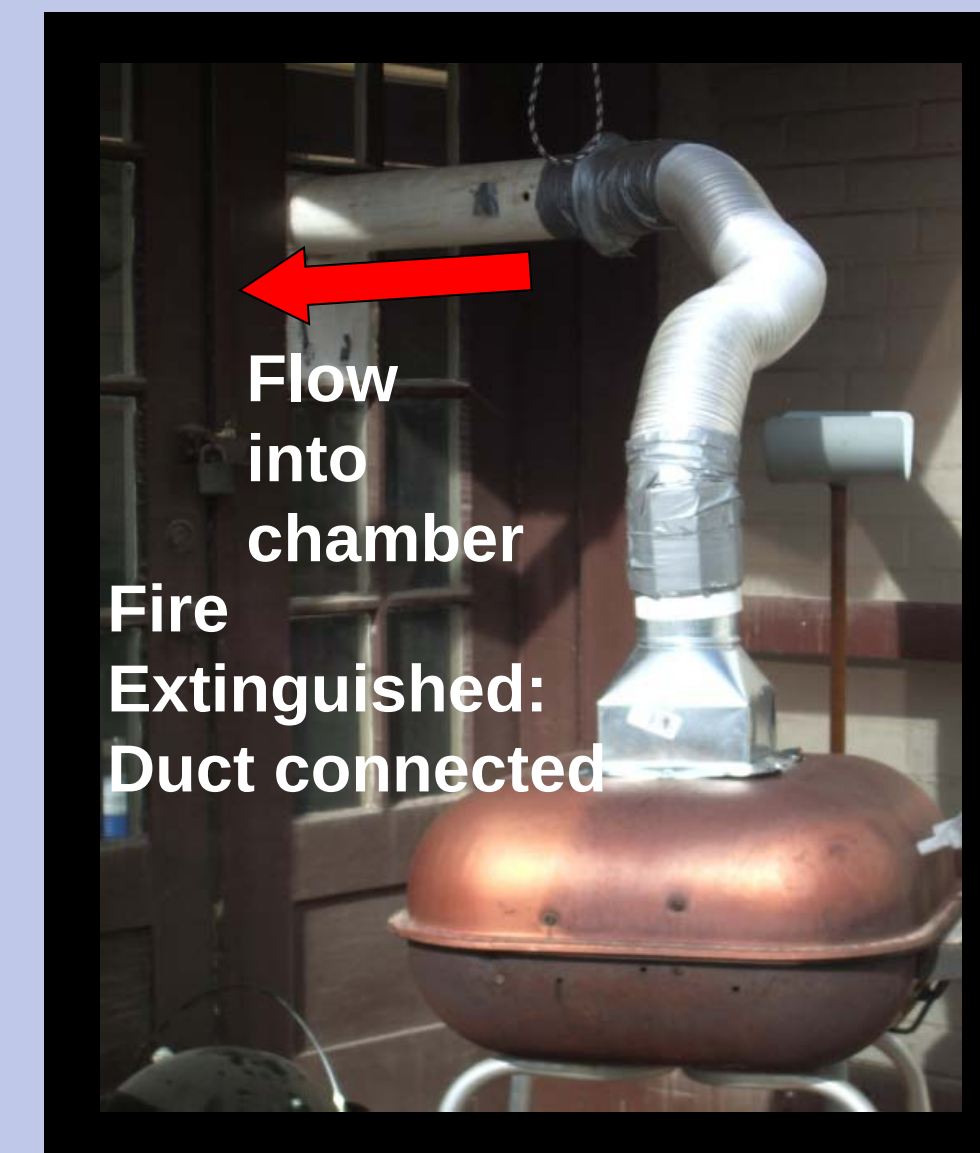
Aggregated respiratory irritant levels penetrating the APR cartridge exceeded the NIOSH REL of 0.1ppm.

3.0 Laboratory Evaluation of CBRN Canisters during Overhaul Exposure⁸

Using the methodology established in the previous study, work focused on measuring penetration of smoke through CBRN-type canisters at concentrations typical of overhaul exposures.

Analytes assessed, included:

- aldehydes,
- PAHs,
- cyanide,
- hydrogen chloride,
- naphthalene,
- carbon monoxide,
- nitrogen dioxide, and
- sulfur dioxide.



Both filtered air and 30-minute chamber testing were evaluated to represent typical field overhaul conditions.

Although contaminant concentrations varied by test, they were in the range of previously conducted field studies.⁵

3.1 Results

Of the fifteen analytes sampled, **none penetrated the respirator canisters** in concentrations at or above any published ceiling limit.

Additional findings:

- Particulate aerodynamic d₅₀ was 0.75 µm (GSD 7.9).
- No particles penetrated the respirator cartridges (0.1 – 10 µm).
- Chemicals with similar health exposures were identified: formaldehyde, acetaldehyde, glutaraldehyde, acrolein, respirable particulates, SO₂, NO₂.
- Irritant exposure indices were computed using the ACGIH short-term exposure limit or ceiling limit because of the short duration (30 minutes) of exposure from overhaul activities.
- For 3 of 4 canister types, at least one test had “high” challenge concentrations (>8.7 irritant index).
- Irritant levels in air filtered by canisters were below unity for all canisters, regardless of the challenge concentration.
- The same 3M FR-64 canister was used in two sequential tests (60 min total), but still performed well.
- Naphthalene and cyanide were not produced in measurable concentrations.

3.2 Conclusions

This work indicates that APRs fitted with CBRN canisters provide protection from combustion analytes and respirable dust present during representative overhaul exposures.

4.0 Future Work

Building from the previous work, which demonstrated effective respiratory protection during laboratory overhaul simulations using CBRN canisters, we will further characterize the effectiveness of the CBRN canisters in overhaul field studies:

- Evaluate canisters worn by firefighters during **actual fire overhaul training activities**.
- Assess combustion concentrations, including cyanide and hydrochloric acid, in air, inside the APR face piece, and via **firefighter contaminant/blood levels**.
- Investigate performance effects against a **wider range of combusted products** (e.g., wool, laminate flooring, adhesives).
- Characterize the influence of varying **humidity** and **temperatures**.
- Assess the influence of longer challenge periods so **breakthrough time** and **service-life** of canisters used during overhaul can be determined.

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